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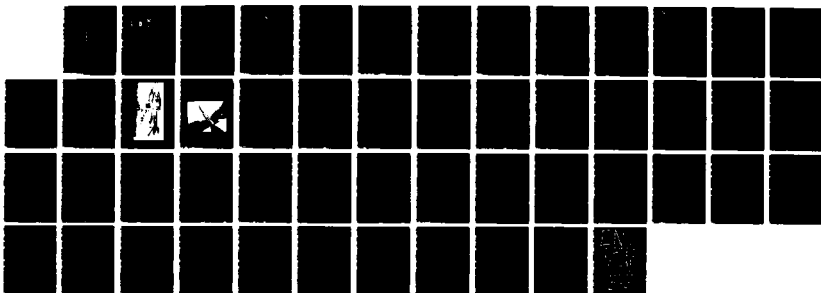
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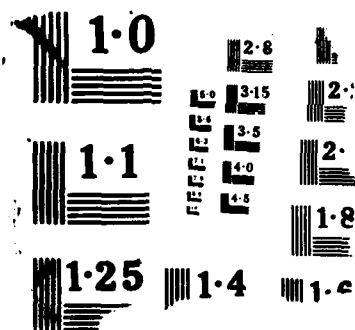
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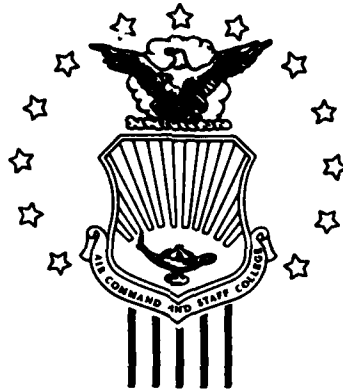


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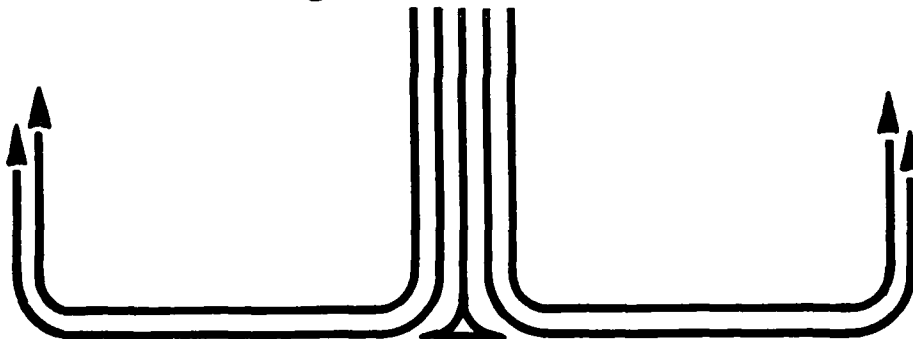
# AIR COMMAND AND STAFF COLLEGE

## STUDENT REPORT

REDUCED FLEXIBILITY IN PROCESSING  
TITAN IV SPACE LAUNCH VEHICLES AT  
CAPE CANAVERAL AIR FORCE STATION

MAJOR MICHAEL G. WOOLLEY 88-2805

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**REPORT NUMBER** 88-2805  
**TITLE** REDUCED FLEXIBILITY IN PROCESSING TITAN IV SPACE  
LAUNCH VEHICLES AT CAPE CANAVERAL AIR FORCE STATION

**AUTHOR(S)** MAJOR MICHAEL G. WOOLLEY, USAF

**FACULTY ADVISOR** MAJOR STEPHEN M. MALUTICH  
ACSC/3824 STUS

**SPONSOR** LT COL JERRY M. JOHNSON  
6555th AEROSPACE TEST GROUP  
CAPE CANAVERAL AFS, FLORIDA

Submitted to the faculty in partial fulfillment of  
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## PREFACE

In the past several years the Air Force has reduced the Titan launch vehicle processing flexibility at Cape Canaveral AFS. These were rational decisions at the time, for the end of expendable launch vehicles was near. The space shuttle had been deemed the primary launch vehicle for the US. However, DOD recognized the need for a complement to the space shuttle, and the Titan IV program was initiated. The shuttle catastrophe and commercialization of space has changed the Titan IV program dramatically. One increased the dependence on the Titan IV; the other places increased demands on Titan processing facilities.

The author acknowledges several people for their great help in the preparation of this study: Lt Col John Hungerford, Maj Steve Wojcicki, and Capt Dan Wyatt, from the 6555th Aerospace Test Group at Cape Canaveral AFS; Mr. Dave Kintigh and Mr. Ed Kitta from Martin Marietta Space Launch Systems at Cape Canaveral AFS; and Maj Craig McAlister from the Titan IV System Program Office at Space Division, Los Angeles AFS, CA. Maj Steve Malutich provided great support as an advisor for this study. The author thanks them all!



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## ABOUT THE AUTHOR

Major Michael G. Woolley arrived at Cape Canaveral 15 November 1983. He was assigned to the Space Launch Vehicles Systems Division of the 6555th Aerospace Test Group. After 5 months as the Launch Vehicles Integration Branch Chief, he became the Titan Operations Branch Chief. In this capacity he was an integral team member of three highly successful Titan 34D launches. When a Titan 34D mishap occurred at Vandenberg AFB, he took on the responsibility of the Test Group's Titan Recovery Team Chief. Furthermore, after another Titan 34D mishap at Vandenberg, he participated as a member of the Missile Mishap Investigation Team. Additionally, because of his expertise in launch vehicles, he was solicited to support the shuttle mishap investigation.

In November of 1986, he became the Titan IV Activation Branch Chief, supervising all aspects of the Titan IV program at Cape Canaveral AFS. He was intimately involved with the design of the vehicle, the launch site activation activities, and the development of the operations concept for the program.

Major Woolley has been in the missile business his entire military career. He started out as a Minuteman III CDB (Command Data Buffer) missile crew member at Minot AFB in North Dakota. From there he went to Wright-Patterson AFB to attend the Air Force Institute of Technology. He earned a Master of Science Degree in Logistics Management. McConnell AFB, Kansas, was his next assignment, where he became a missile maintenance officer, specializing in propellant loading. Eventually he became the job control officer for the missile wing. Then he was able to get his assignment to the 6555th Aerospace Test Group. While there, he was selected for major and to attend Air Command and Staff College.



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### REPORT NUMBER

88-2805

### AUTHOR(S)

Major Michael G. Woolley, USAF

### TITLE

REDUCED FLEXIBILITY IN PROCESSING TITAN IV SPACE LAUNCH VEHICLES AT CAPE CANAVERAL AIR FORCE STATION

I. PURPOSE: To determine if the current Titan IV Space Launch Vehicle processing capabilities permit DOD to meet the projected Titan IV Mission Model.

II. PROBLEM: In the past several years decisions have been made which have reduced Titan processing facilities' flexibility. The Space Transportation System (STS) was deemed the primary launch system. The end of expendable launch vehicles was in sight. However, the space launch environment has changed dramatically. The STS Challenger mishap and the encouragement of commercialization of space has greatly affected the Titan IV program. The shuttle tragedy occurred just 10 months into the Titan IV program development. Originally only 10 vehicles were ordered with launches scheduled at the rate of 2 per year for 5 years. Because of the STS standdown, many DOD program managers decided to switch from the shuttle and fly on the Titan IV. Now up to 48 vehicles may be procured with an expectation to launch at least 4 per year starting in 1990 and a desire to launch 6 per year in the out years. The processing facilities may not have the flexibility to achieve that goal. The ability to meet the mission model is

## CONTINUED

compounded by the commercialization effort of the primary military launch contractors. They intend to use many of the facilities the military presently uses for its launches.

III. DATA: The Titan IV contractor, Martin Marietta, bases its ability to comply with the contract on a "green light" schedule. This allows no contingency time for major anomalies which may greatly affect a facility's throughput. Moreover, the 23-vehicle contract calls for launches four times per year, yet the most Titan vehicles launched in a year from Cape Canaveral is three. Working the nominal schedule of 8 hours a day, 5 days a week, the contractor falls short of the 4-per-year launch requirement in four different areas. Only 3.6 core vehicles can process through the Vertical Integration Building (VIB) in a year. The launch complex will only support 3.5 launches per year. The transporters which the core vehicle is placed on for most of its processing can only support 3.6 launches per year. Finally, the Payload Fairing (PLF) Annex can only produce 2.9 payload fairings if the technicians work the normal shift. Martin Marietta recognizes these shortfalls and plans to work double shifts, 6 days a week in the PLF Annex and will work extended shifts and weekend overtime to make up the needed time in the other areas which have shortfalls.

IV. CONCLUSIONS: The Titan IV Mission Model can not be accomplished doing "business as usual." More technicians must be added. Additionally, for the facility that is capable of processing only one component at a time, a problem with the facility or a component in the facility will serially impact the launch schedules of all vehicles which follow it. Redundancy built into the processing facilities can eliminate the problem by providing scheduling flexibility. This will further allow for a greater surge in processing capability should the need arise.

V. RECOMMENDATIONS: Increase Titan IV processing facilities' flexibility. This should be done as follows: build more PLF processing capability; build a new Solid Motor Assembly Building; convert another transporter to the Titan IV configuration; construct the Centaur Processing Facility somewhere other than the VIB; and configure another vertical cell of the VIB to process Titan IV core vehicles. Furthermore, when cost tradeoff studies are performed, flexibility must also be considered along with capacity.

## CHAPTER I

### INTRODUCTION TO RESEARCH

#### BACKGROUND

In the past several years the Air Force has reduced the Titan launch vehicle processing flexibility at Cape Canaveral AFS. These were rational decisions considering the constraints placed on the launch program at the time. However, the environment surrounding the Titan program has changed drastically, and the need for flexibility in processing these highly essential vehicles must be addressed. If it is not, Titan IV Space Launch Vehicles might not be processed fast enough to meet the desired mission models and hence, the needs of U. S. national security.

#### RATIONALE FOR FLEXIBILITY REDUCTION

National Security Decision Directive 42 (NSDD-42) issued on 4 July 1982 "mandated the Space Transportation System (STS) to be the primary space launch vehicle for both national security and civil government missions. Expendable launch vehicle operations were only to be continued until capabilities of the STS became sufficient to meet [US government] needs and obligations" (4:50). Once the STS became operational, it was to be capable of routinely placing satellites into orbit much cheaper than expendable launch vehicles (7:13). DOD had launch priority on the STS, and the proposed 24-per-year launch rate met DOD needs. Therefore, there was no need to continue using expendable launch vehicles. As a result, Congress only funded expendable launch vehicle programs, such as the Titan, Atlas, and Delta, for the remaining vehicles on the manifest (4:50). Since the end of the Titan program was in sight, several decisions were made which reduced the capability to simultaneously process several Titan vehicles for launch.

Because the end of the program was near, DOD wanted to use the Titan processing facilities wisely. In 1978, when a location for the Shuttle Processing Integration Facility (SPIF)

was being considered, the Titan's Solid Motor Assembly Building (SMAB) was the logical choice. The remaining five Titan 34D launch requirements were spread out enough that having only two cells should not have hindered the processing of the vehicles.

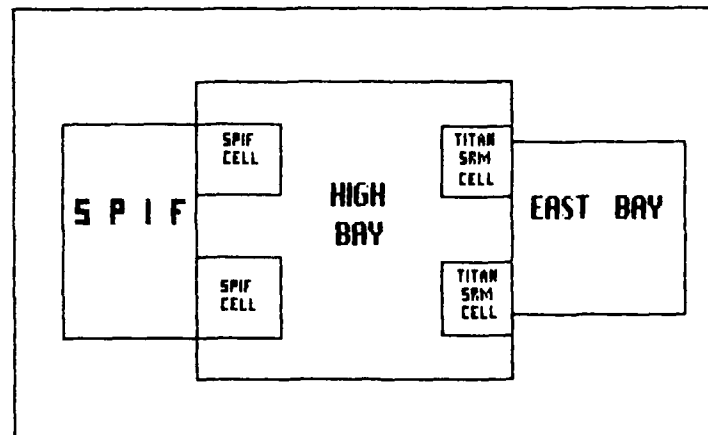


FIGURE 1.1  
SOLID MOTOR ASSEMBLY BUILDING

Therefore, DOD decided to convert two of the four Titan solid rocket motor (SRM) build-up cells into the processing cells for the SPIF. This reduced the capacity for stacking and storing Titan SRMs by 50 per cent and thus, the flexibility of processing SRMs.

Furthermore, in 1985, because DOD was only buying 10 Titan IV vehicles, the Air Force agreed to put the Centaur processing facility in the Vertical Integration Building (VIB) Cell 3. This reduced core vehicle storage in the vertical cells by 25 per cent. The reduction was acceptable to the schedule, which required only two launches per year, and the cost to modify the cell was less than building a new facility (13:--).

#### HOW THE ENVIRONMENT HAS CHANGED

In 1984, the Department of Defense was able to convince Congress there was a need for a complement to the STS (1:10). In March 1985, a contract for 10 Complementary Expendable Launch Vehicles (CELV) was awarded to Martin Marietta Aerospace. (The CELV program, referred to as Titan 34D7, was later designated the Titan IV program.) The contract called for the 10 vehicles to be launched from Cape Canaveral at the rate of 2 per year for 5 years. Even with the reduced flexibility of stacking and storing SRMs, the contractor could achieve the schedule easily since only one vehicle would need to be processed at a time.

The Space Shuttle Challenger catastrophe, which occurred 28 January 1986, greatly impacted the "US Space Acquisition Master Plan" (19:--). The initial estimate for the STS to standdown was 24 months. NASA later announced the standdown would be at least 30 months. The next launch is currently scheduled for late July or early August of 1988 (6.1). Several programs needed to launch as scheduled to replenish their constellations. Newer programs needed to launch in order to develop their constellations. The backlog was tremendous. According to Secretary Aldridge, 21 high priority payloads would be impacted by a 2-year standdown (2:52).

Therefore, DOD, with Congress' blessing, decided to order additional expendable launch vehicles. The number of Titan IVs increased from the initial 10 to 23 (5:1319). The McDonnell Douglas Astronautics Company won the contract to launch the Global Positioning System (GPS) satellites on the Deita II vehicle. Other government satellite programs opened bids for expendable launch vehicle contracts. Presently, demand is so great to get assets into space that there are discussions to increase the Titan IV purchase from 23 vehicles up to 48 vehicles (18:--). Now, instead of launching just two Titan IV vehicles per year from Cape Canaveral, at least four per year is the minimum beginning in 1990.

Another major change in the launch vehicle environment is the commercialization of space. On 15 August 1986, President Reagan issued a statement directing government support of commercial launch efforts (5:1319). The directive tasked government agencies to aid in the development and operations of private contractors' launch programs, assisting as much as possible without subsidizing their efforts (3:165). This greatly affects military launch vehicle processing because many of the viable contractors in the private launch arena (such as Martin Marietta, General Dynamics, and McDonnell Douglas) currently launch military satellites and intend to use the same facilities as much as they can for their private endeavors.

This impacts the Titan IV program tremendously. Not only must there be at least four Titan IV launches per year, beginning in 1990, with a system initially designed to process and launch only two per year, but it must share critical facilities and resources with Martin Marietta's and possibly General Dynamics' commercial efforts.



1 Motor Inert Storage  
2 Segment Arrival Storage  
3 Receipt-Inspection Storage  
4 Segment Ready Storage  
Vertical Integration Building

6 Press Site  
7 Warehouse  
8 Solid Motor Assembly Building  
9 Launch Complex 40  
10 Launch Complex 41



FIGURE 1.2  
TITAN PROCESSING FACILITIES (8:8)

## PROCESSING FLOW AT CAPE CANAVERAL

DOD constructed the Titan facilities at Cape Canaveral so that several vehicles could be simultaneously processed in a modular fashion. Talking to people associated with the inception of the Titan launch program reveals the initial concept was to launch as many as 60 Titan vehicles from the Cape in a year. However, due to budgetary constraints, launch requirements, and other reasons, all the facilities required to achieve such a launch rate were not constructed (14:-- ,16:--). To date, the most Titan vehicles launched from the Cape in a calendar year is three (9:2).



FIGURE 1.3  
TITAN IV SPACE LAUNCH VEHICLE (11:2)

The fully integrated Titan IV launch vehicle consists of five components: the core vehicle, the solid rocket motors, the upper stage, the payload fairing, and the satellite. These components are processed independently in separate facilities. Once DOD decides to launch a particular vehicle, its designated components are mechanically assembled and electrically checked out; then it is launched. The following is a description of that process (8:3-32).

The core vehicle is not fully assembled when it arrives at the Cape. Martin Marietta Aerospace ships the basic superstructure, primarily made up of the liquid fuel tanks, from Denver, and the engines arrive from Sacramento. Other contractors ship the instrumentation packages and other electrical components from other cities. They are integrated in the Vertical Integration Building (VIB), then electrically tested to verify system integrity. The contractors perform the assembly in several areas of the VIB.

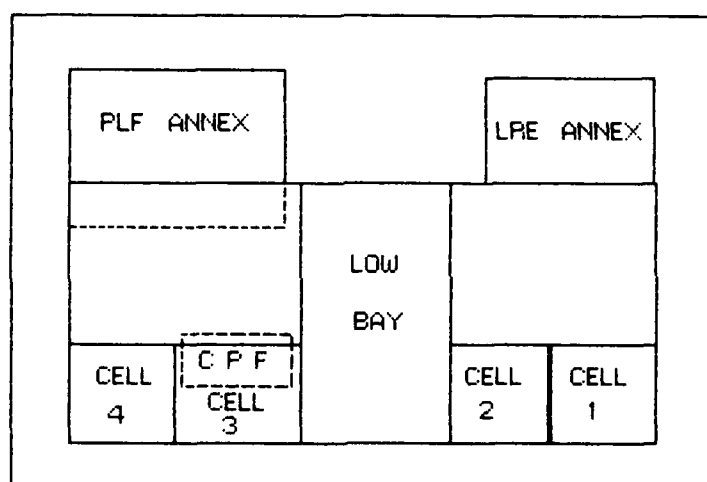


FIGURE 1.4  
VERTICAL INTEGRATION BUILDING

The engines are received, inspected, and initially processed in the Liquid Rocket Engine Annex (LRE Annex). The core vehicle superstructure is received horizontally on a trailer and inspected in the low bay. Some of the electrical and mechanical components may be installed while it is horizontal. Once the technicians mount the engines onto the superstructure, they raise the entire assembly to the vertical position and set it on a transporter located in one of the four vertical cells. Then it is electrically checked out in Cell 2.

After that, it remains in Cell 2 or is stored in Cell 4 until it is designated for integration with the other components for launch. (Cell 1 is used for Titan 34D electrical checkout, and the upper levels of Cell 3 are being converted to the Centaur Processing Facility.)

As stated before, technicians process solid rocket motors (SRMs) independently of the core vehicle. A Titan IV SRM consists of a stack of seven standard segments, an aft segment, a forward segment, and other hardware. Specially designed railroad cars transport the segments cross-country to the Receipt-Inspection-Storage (RIS) building where technicians inspect them. The contractors then transport each segment to the x-ray facility for inspection and then store them in either the RIS or the Segment Ready Storage (SRS) building.

When it is time to stack the SRMs designated for launch, technicians transport the segments to the Solid Motor Assembly Building (SMAB) on railroad cars. Titan IV launch vehicles use two solid rocket motors. For a Titan IV vehicle the technicians stack the aft segment and only five standard segments in the SMAB; the other two standard segments and the forward segment are placed on top of the stack at the launch complex. After the technicians stack the five segments of each SRM, they move the core vehicle from the VIB to the SMAB on the transporter. At the SMAB they place the SRMs on the transporter and mechanically mate them to the core vehicle. Then the core vehicle and the SRMs are moved to the launch complex on the transporter. Once there, the technicians put the other two segments and the forward closure in place and then electrically and mechanically test the fully stacked SRMs. Mechanical tasks are also performed on the core vehicle.

There are presently three upper stage configurations the Titan IV core vehicle may use: the Inertial Upper Stage (IUS), the Centaur, and a configuration with no upper stage (NUS) above the second stage of the core vehicle.

The IUS is processed in several areas at the Cape. Technicians receive and inspect the IUS structural and mechanical assemblies in Hangar E, while other technicians receive and inspect its solid rocket motors and ordnance items in the ordnance area of the Cape where they are stored. When higher headquarters selects a particular IUS to fly on a Titan IV, the technicians transport the components to the SMAB east bay. There it is mechanically assembled and electrically tested. It is stored in the east bay until it is transported to the launch complex. Once on complex the technicians mate it to the core vehicle and electrically test it.

The Centaur upper stage processing flow is similar to the IUS flow. The hardware is received and inspected in Hangar J. When a Centaur is designated for build up, the components are transported to the Centaur Processing Facility (CPF) on the upper levels of the VIB Cell 3 for mechanical assembly and electrical testing. The payload fairing boattail section is installed around the Centaur while it is still in Cell 3. Once assembled and checked out, the Centaur is stored on the floor of Cell 3. At the appropriate time, technicians transport it to the launch complex and mate it to the core vehicle. Technicians then perform mechanical operations and electrical tests.

The payload fairing (PLF) is received and inspected in Hangar M, then transported to the PLF Annex in the VIB. There technicians mechanically and electrically prepare it for flight. If a PLF is designated for a Centaur upper stage, the base section is taken to the CPF when the Centaur is ready for it. The technicians take the forward sections to the launch complex after the core vehicle is on the complex and install it around the satellite at the appropriate time. For the IUS configuration, the PLF is transported to the complex after the core vehicle is on complex. It is stored in the Mobile Service Tower (MST) Environmental Shelter (ES) until placed around the IUS and satellite. For a configuration with no upper stage, the PLF is transported to the complex after the core vehicle arrives and is stored in the ES until it is placed around the satellite.

The satellite processing is performed outside the Titan area and will not be discussed in this paper. The satellite is brought to the complex after the upper stage has been installed or, in the no upper stage configuration, after the SRM stacking is complete. It is mated to the core vehicle or upper stage, electrically tested, then covered by the PLF. After the launch crew fuels the vehicle and performs verification tests, the vehicle is launched. Then the complex is refurbished. During the complex refurbishment the transporter is moved to the Transporter Refurbishment Area for repairs. Once it is ready, a core vehicle is placed on it, and the cycle begins again.

#### RESEARCH QUESTION

The following question provides the direction for this research: Will the current Titan IV processing capabilities permit the Air Force to meet the projected Titan IV Mission Model?

## RESEARCH METHODOLOGY

The research question will be answered by pursuing the following course of action. First, the throughput capacities of the Titan facilities will be determined. The mechanics of this assessment will be discussed in the next chapter. Then the mission model will be analyzed from the perspective of throughput capabilities. This will initially be done using a "green light" schedule. Then the mission model will be evaluated in light of some permutations that have happened on the Titan 34D program. Once this is accomplished, recommendations will be formulated and presented.

## CHAPTER 11

### THROUGHPUT CAPACITIES OF TITAN IV FACILITIES

In order to determine whether Cape Canaveral can achieve the desired Titan IV Mission Model, throughput capacity for each facility must be determined. This research effort defines throughput capacity as how many components can be processed through the facility within a given period of time. This study's time period is one year.

The contractors schedule work on the launch vehicles by shifts. It is possible to work multiple shifts in a day. Therefore, work effort will be based on shifts not days. The Titan IV contract specifies the normal work effort for the contractors will be one 8-hour shift, 5 days a week. The formula to determine the throughput capacity for a particular facility is as follows.

$$\frac{\frac{\text{days/year}}{\frac{\text{shifts/component}}{\text{shifts/day}}} + \text{weekend days/component}}{1} = \text{components/year}$$

FORMULA 2.1  
COMPONENTS/YEAR

The contract also specifies the contractor is allowed 12 holidays per year; thus, only 353 days will be available in a year.

The number of shifts required to process a component is based on a 22-year history of assembling and launching Titan vehicles. During this time, the contractor has become extremely proficient at predicting the number of shifts needed to process a particular component. There is some time factored into the schedule to keep minor problems from impacting the schedule. However, it allows no time for an anomaly which might require additional shifts to resolve. This is called a

"green light" schedule. Unique problems can develop during a processing cycle which are impossible to predict and take days, weeks, or months to resolve, or the processing can proceed smoothly with no major problems. Padding the schedule with additional shifts to accommodate unforeseen problems is not realistic. Therefore, because it is the best prediction available and is accepted throughout the industry, this study uses the "green light" schedule as the basis for computations.

The computations to determine throughput capacity assume the facility is able to accept the component when it is designated for processing. Therefore, once one component completes processing in a facility, it is followed immediately by another component. Additionally, the figures do not account for facility outages due to periodic maintenance requirements. These may range from one hour (such as changing oil in a compressor) to several weeks (such as complete corrosion control on the launch complex Mobile Service Tower). They are normally scheduled around the processing schedules when the facility is available for that type of work.

#### CORE VEHICLE PROCESSING THROUGH THE VERTICAL INTEGRATION BUILDING

As stated in Chapter 1, the contractor ships the core vehicle to the VIB unassembled. The contractors' technicians process it in several areas of the VIB, such as the low bay, the vertical cells, and the Liquid Rocket Engine Annex (see Fig 1.4). The nominal effort to process the core vehicle from the first component arrival at the Cape until it is ready for transfer to the Solid Motor Assembly Building is 70 shifts (15:--). Working 5 days a week, 28 weekend days can occur, depending on which weekday the first shift begins. Using Formula 2.1, Equation 2.1 reveals that only 3.6 vehicles can be processed through the VIB in one year.

$$\frac{353 \text{ days/yr}}{\frac{70 \text{ shifts/core vehicle}}{1 \text{ shift/day}} + 28 \text{ weekend days/core vehicle}} = 3.6 \text{ core vehicles/year}$$

EQUATION 2.1  
CORE VEHICLES/YEAR



SOLID ROCKET MOTOR SEGMENT PROCESSING THROUGH THE  
RECEIPT-INSPECTION-STORAGE AND XRAY FACILITIES

As a result of the Vandenberg AFB Titan mishap on 18 April 1986, solid rocket motor segments now require several non-destructive tests (NDT) prior to stacking. Some non-destructive testing and observations were performed on segments prior to the mishap, but several new tests which consume many hours are now conducted. These new tests are still in the development stage and, as more is learned about the results and values of the tests, the testing requirements might be reduced. However, since the decision has not yet been made, this study will use the shift figures as of 8 June 1987 (15:--).

NDT requires 147 shifts for a full set of solid rocket motors (15:--). The work schedule calls for three 8-hour shifts, 6 days a week. That results in 49 weekdays with 8 weekend days possible. Equation 2.2 indicates 6.2 SRM sets/year can be processed from receipt to the time they are ready for stacking.

$$\frac{353 \text{ days/yr}}{\frac{147 \text{ shifts/set}}{3 \text{ shifts/day}} + 8 \text{ weekend days/set}} = 6.2 \text{ sets/yr}$$

EQUATION 2.2  
SRM SETS/YEAR THROUGH NDT

SOLID ROCKET MOTOR PROCESSING THROUGH THE  
SOLID MOTOR ASSEMBLY BUILDING (SMAB)

After segments are selected for stacking, the technicians move them to the SMAB. Only the aft segment and five standard segments per SRM are stacked in the SMAB. This activity takes 25 shifts with 10 weekend days possible (15:--). An additional 5 days are added due to the scheduling impacts encountered from other activities performed in the SMAB, such as SPIF component movement in the high bay or lifting IUS solid rocket segments.

When the SRMs are ready to mate, technicians transfer the core vehicle to the SMAB on the transporter. The SRMs are placed on the transporter and connected to the core vehicle. This process takes 4 shifts which may encompass 2 weekend days. These figures are combined with those above to yield 29 shifts/set in the SMAB with 12 weekend days possible (15:--). Thus, Equation 2.3 results in 7.7 sets/yr.

$$\frac{353 \text{ days/yr}}{\frac{29 \text{ shifts/set} + 12 \text{ weekend days/set} + 5 \text{ impact days/set}}{1 \text{ shift/day}}} = 7.7 \text{ sets/yr}$$

EQUATION 2.3  
SRM SETS/YEAR THROUGH SMAB

INERTIAL UPPER STAGE PROCESSING IN THE SMAB EAST BAY

One hundred and three shifts are required to build up and check out an IUS (15:--). Fortytwo weekend days are possible. There are two work areas in the east bay; this provides the capability to build two IUSs at a time. This must be factored into the IUSs/yr equation. The result is 4.8 IUSs/yr.

$$\frac{353 \text{ days/yr}}{\frac{103 \text{ shifts/IUS} + 42 \text{ weekend days/IUS}}{1 \text{ shift/day}}} = 2.4 \text{ IUSs/yr}$$

EQUATION 2.4  
IUSs/YEAR THROUGH A WORK AREA

$$2.4 \text{ IUSs/yr per work area} \times 2 \text{ work areas} = 4.8 \text{ IUSs/yr}$$

EQUATION 2.5  
IUSs/YEAR THROUGH THE SMAB

CENTAUR PROCESSING THROUGH THE CENTAUR PROCESSING FACILITY  
IN THE VIB

The effort to prepare the Centaur from its receipt at the Cape until it is ready to be moved to the launch complex is scheduled for 43 shifts, encompassing 18 weekend days (15:--). This assumes the payload fairing boattail section is ready for installation when required. Inserting the data into the formula reveals 5.8 Centaurs can be processed in a year.

$$\frac{353 \text{ days/yr}}{\frac{43 \text{ shifts/Centaur}}{1 \text{ shift/day}} + 18 \text{ weekend days/Centaur}} = 5.8 \text{ Centaurs/yr}$$

EQUATION 2.6  
CENTAURS/YEAR

#### PAYLOAD FAIRING PROCESSING IN THE PLF ANNEX OF THE VIB

Payload fairing processing in the annex is scheduled to take 86 shifts, encountering 34 weekend days (15:--). Equation 2.7 yields 2.9 PLFs/yr.

$$\frac{353 \text{ days/yr}}{\frac{86 \text{ shifts/PLF}}{1 \text{ shift/day}} + 34 \text{ weekend days/PLF}} = 2.9 \text{ PLFs/yr}$$

EQUATION 2.7  
PLFs/YEAR

#### SATELLITE OFF-SITE PROCESSING

Satellite processing accomplished outside the Titan facilities area should not affect the processing of the Titan IV vehicles. It is outside the scope of this study and will not be addressed.

#### LAUNCH COMPLEX PROCESSING

Launch complex processing begins when the transporter with the core vehicle and SRMs arrives. There are 38 shifts until the satellite is mated with the Titan IV (15:--). Tasks include stacking the additional SRM segments, mating the upper stage, placing the PLF in the environmental shelter, and conducting the mechanical and electrical tests associated with these components. Sixteen weekend days can occur during this

time. This period is referred to as "core arrival to mate."

Satellite processing time on complex varies from satellite to satellite, so a standard 28 days is scheduled from mate to launch (15:--). The work week is 7 days; thus, weekend days are not a factor during this time period.

After launch, there are 13 shifts of refurbishment work performed on the launch complex before another launch vehicle can arrive for processing (15:--). Six weekend days are associated with this effort.

Adding these three time periods together produces the number of days the launch complex is occupied for one launch. The sum is the time it takes from one launch until another vehicle can be launched. This is known as the "launch-to-launch capability." Equation 2.8 yields 101 days. Dividing this figure into the available workdays in a year provides the launches possible from this complex in a year. The result is 3.5 launches per year as indicated by equation 2.9.

Core arrival to mate	38 shifts + 16 weekend days	54 days
Mate to launch	28 shifts	28 days
Refurb to core arrival	13 shifts + 6 weekend days	<u>19 days</u>
Launch-to-launch capability		101 days

EQUATION 2.8  
LAUNCH-TO-LAUNCH CAPABILITY

$$\frac{353 \text{ days/yr}}{101 \text{ days/launch}} = 3.5 \text{ launches/yr}$$

EQUATION 2.9  
LAUNCHES/YEAR FROM A COMPLEX

TRANSPORTER AVAILABILITY

The transporters are not fixed facilities, but they also have processing capacities. Once a core vehicle is set on a transporter to begin its processing, it normally remains on that transporter until launch. This encompasses 120 shifts (consisting of transporter refurbishment after launch and the

time it is supporting its next core vehicle) with 48 weekend days possible during that time. This 168 days added to the 28 straight days from satellite mate to launch results in the transporter being used for 196 days per launch. Dividing that figure into days available in the year yields 1.8 launches from a transporter per year (Equation 2.10). There are only 2 transporters available which results in 3.6 launches per year from the transporters. (The other 2 transporters remain configured for Titan 34D vehicles and will be used for Martin Marietta's commercial launch vehicles).

$$\frac{353 \text{ days/yr}}{196 \text{ days/launch}} = 1.8 \text{ launches/yr}$$

EQUATION 2.10  
LAUNCHES FROM A TRANSPORTER/YEAR

Core Vehicle	
VIB processing	3.6 vehicles/yr
Solid Rocket Motor	
RIS & X-ray processing (triple shifts)	6.2 sets/yr
SMAB high bay	7.7 sets/yr
Inertial Upper Stage	
SMAB east bay	4.8 IUSs/yr
Centaur	
VIB Cell 3	5.8 Centaurs/yr
Payload Fairing	
VIB PLF Annex	2.9 PLFs/yr
Launch Complex	3.5 launches/yr
Transporters	3.6 launches/yr

TABLE 2.1  
TITAN IV PROCESSING  
NORMAL SHIFTS (13:--)

As stated at the beginning of this chapter, these computations are based on a "green light" schedule which depends on components, their subcomponents, and the facilities being available when necessary. This means the facility with the least component per year capacity is the limiting factor in achieving the desired launch rate. Table 2.1 indicates the PLF Annex can only produce 2.9 PLFs per year. This production rate cannot support four launches per year.

Martin Marietta is addressing the shortfall by scheduling two 10-hour shifts 5 days a week. The processing of a payload fairing includes a great deal of time to allow curing of materials applied to the PLF. This prevents calculating the throughput by dividing the number of shifts by 2 because the estimation of shifts to process the PLF allowed the cure time to occur after the shift. However, when two shifts are worked in the same day, some of the cure time will occur during those shifts, and technicians will not be able to work during the curing time. Therefore, to make the shifts most efficient when working two per day the contractor has decided to work 10-hour shifts. It takes 60 workdays working 2 10-hour shifts to process a PLF (15:--). Equation 2.11 yields 4.2 PLFs per year.

$$\frac{353 \text{ days}}{60 \text{ days/PLF} + 24 \text{ weekend days}} = 4.2 \text{ PLFs/yr}$$

EQUATION 2.11  
PLFs/YEAR WORKING TWO 10 HOUR SHIFTS

The contractor also feels that by working selected shifts longer than 8 hours and working some weekends in other facilities which don't meet the launch rate, they can achieve the contractual 4 per year launch rate (17:--).

## CHAPTER III

### MISSION MODEL ATTAINMENT

The present contract for 23 Titan vehicles (commonly known as Restructure 11) calls for a launch rate of 4 per year. Table 3.1 indicates when Martin Marietta intends to launch the 17 Titan vehicles slated for launch from Cape Canaveral. (The other 6 will be launched from Vandenberg AFB) It indicates there will be five launches in 1993.

	89	90	91	92	93
T IV/IUS/NUS	2	1	1	2	2
T IV/CENTAUR	0	1	3	2	3

TABLE 3.1  
TITAN IV PROGRAM SCHEDULE (10:1)

However, the desired mission model as of 15 June 87 (Table 3.2) identifies the need to launch five Titan IV missions a year from Cape Canaveral beginning in 1990. This desire is due to the massive backlog created by the shuttle catastrophe and the delay in its return to operation. As the delay lengthens more programs are seeking launch opportunities on Titan IVs. Due to contractual processing time constraints, the contractual mission model does not truly reflect the desired mission model (18:--).

	88	89	90	91	92	93
T 34-D	2	2	0	0	0	0
T IV/IUS/NUS	0	3	2	3	1	3
T IV/CENTAUR	0	0	3	1	4	2
IUS/STS	2	3	3	3	3	3
T III	0	3	5	5	4	5
(Commercial)						

TABLE 3.2  
6555 ASTG LAUNCH VEHICLE DIVISION  
INITIAL LAUNCH CAPABILITY MISSION MODEL FY 88-93 (12:--)

Table 2.1 indicates there are several facility throughput capacities less than 4 per year. Therefore, the processing team will not be able to "do business as usual." Work schedules will have to be modified.

The contractor developed the work force using 8-hour shifts worked 5 days a week as the basis. The current work force is not manned to sustain extensive schedules of multiple shifts and longer work weeks. In order to meet the mission model, more technicians will have to be added to the processing team. In fact, Martin Marietta is using their own funds to hire 30 additional technicians to handle the increased work effort until the additional buy of up to 25 more Titan IVs is negotiated (17:--).

By working two 8-hour shifts 6 days a week instead of the normal one 8-hour shift 5 days a week the information contained in Table 2.1 changes as noted in Table 3.3. The computations for Table 3.3 are contained in Appendix A.

Table 3.3 indicates the contractor can meet the mission model using the double shift 6 day per week "green light" schedule. The problem is the "green light" schedule uses practically all of the facilities' capacity. Only 8 hours, 6 days a week and the 24 hours of the seventh day are available for periodic maintenance and modifications in most of the facilities. For the PLF Annex, working the preferred two 10-hour shifts (indicated on page 17) leaves only 4 hours, 6 days a week and the seventh day. The SRM x-ray process is accomplished with triple shifts; thus, only the 24 hours of the seventh day are available. These same hours are all that is available to make up schedule and for surge processing. This means that a major anomaly for one vehicle will have a serial effect on the following vehicles.



Core Vehicle	
VIB Processing	8.6 vehicles/yr
Solid Rocket Motors	
RIS & X-ray Processing	6.2 sets/yr (triple shifts 6 days/wk)
SMAB High Bay	15.3 sets/yr
Inertial Upper Stage	
SMAB East Bay	11.6 IUSs/yr
Centaur	
VIB Cell 3	13.6 Centaurs/yr
Payload Fairing	
VIB PLF Annex	5.4 PLFs/yr (triple shifts 6 days/wk)
Launch Complex	6.0 launches/yr
Transporter	7.2 launches/yr

TABLE 3.3  
TITAN IV PROCESSING  
DOUBLE SHIFTS SIX DAYS/WEEK (13:--)

As stated before, we have reduced the flexibility of processing multiple components simultaneously by reconfiguring facilities for other uses and by constructing new facilities to process only one component at a time. SRM processing in the Solid Motor Assembly Building was reduced by 50 percent when the Shuttle Payload Integration Facility was constructed using two of the Titan SRM stacking cells. Hence, only one SRM set can be processed at a time. The Vertical Integration Building vertical cell usage was reduced 25 per cent by constructing the Centaur Processing Facility in its upper levels and designating its floor space as storage for Centaurs. The decision to convert only two of the four transporters for Titan IV vehicle use reduced their scheduling flexibility by 50 per cent. When the X-ray Facility was constructed, it was built with only one horizontal x-ray cell. The construction of the four non-destructive inspection stations in the RIS limited operations to only one segment through each of the different stations. This has reduced the contractor to processing only one vehicle at a time through most of the facilities.

Because of the present single vehicle flow limitation in some facilities, an anomaly for one vehicle results in a serial impact for all other vehicle flows following it. For instance, if it is necessary to return Titan IV-3 to the VIB (this has been done twice in the past three Titan 34D vehicle flows), the SRMs must be placed in the SMAB cells. Since there are only 2 cells, if another set of SRMs are stacked, they must be placed on another transporter or destacked. If they are destacked, Titan IV-3 must wait until that is accomplished. That time plus the time Titan IV-3 SRMs remain in the cells must be added together to calculate the time the following vehicles' launches must be delayed. Titan 34D-8 returned to the SMAB on 15 July 86 to be destacked. The SRM destacking was completed in 70 days with the team working double shifts, 6 days a week. If that occurred for Titan IV-3, then during that year only 6.2 SRM sets could be processed through the SMAB and one of those would probably be assigned to Titan IV-3. This leaves only 5.2 others left and their scheduled launch date would be impacted by the 70 days it took to destack Titan IV-3's SRMs. If four stacking cells were available in the SMAB this operation would not impact the other vehicles.

Dual processing capability allows quicker resolution of some anomalies. Sometimes an anomaly occurs that requires inspection of other vehicles. These vehicles must be in the same configuration as the anomalous vehicle to determine if a similar situation exists. For example, a noise was heard during the inspection of T34D-3's second stage turbopump assembly while it was undergoing processing in Cell 1. Fortunately T34D-8 was in Cell 2. This allowed an inspection of a vehicle in the vertical position which was much more beneficial than an inspection of a horizontal core vehicle in the low bay or at the plant in Denver. A noise might not be produced because the vehicle is horizontal rather than vertical.

In order to meet the mission model most of the facilities will have to continuously operate; facility modifications and periodic maintenance efforts will impact the throughput capacity. These capacities were based on a "green light" schedule which expected the facility to be available to process a component immediately after the prior component is finished processing through it. This allows no time for facility modifications or periodic maintenance except for the evenings and weekends. Some modifications, such as welding, must be performed without a component present which means that they must be accomplished between component processing. This occurred when the Mobile Service Tower and Umbilical Tower stairs had to be replaced when no vehicle was on Complex 40. It took several weeks to complete. This decreases the

facility's throughput capacity.

If a facility must process around the clock in order to meet the mission model, then even the evenings and weekends are not available. Once a facility becomes inoperative due to infrequent maintenance, the time it takes to get the facility operational is normally longer and more expensive than the time it would have taken to perform the periodic maintenance.

Another problem with meeting the mission model is the contractors' commercial efforts. Martin Marietta is planning to use a vehicle similar to the Titan 34D which they call a Titan III. General Dynamics proposes to use a Centaur upper stage in commercial efforts. They will be using many of the same facilities to process and launch their space launch vehicles. Because only one set of SRM stacking cells is available in the SMAB, DOD SRMs can not be stacked at the same time commercial SRMs are stacked. In fact it will take 5 shifts to convert the cells from Titan IV SRMs to Titan III SRMs and five more to revert back (15:--). Furthermore, Titan III SRMs take 14 more shifts to stack and mate because they are fully stacked and checked out in the SMAB cells (15:--). These additional shifts greatly reduce the SMAB throughput capacity. If four Titan IVs process through the SMAB in a year, only 2.1 Titan IIIs can process through. This reduces the throughput capacity from 7.7 sets/yr to 6.1 sets/yr. Computing the figures for working double shifts, 6 days a week reveals that for four Titan IVs processed through the SMAB only 7.1 Titan III SRMs can be processed. This shows a reduction from 15.3 Titan IV SRM sets through the SMAB down to only 11.1 Titan IV/Titan III SRM sets per year. These computations are contained in Appendix B.

Other facilities will also be affected by the commercial effort. A DOD mission can not be launched from the dual-compatible launch complex while the contractor is processing a commercial vehicle for launch on that launch complex. Moreover, the SRM NDT and x-ray facilities reach their maximum capacity at 6.2 sets per year working triple shifts 6 days a week. Yet the contractor is projecting up to 5 commercial launches per year. That coupled with only 4 DOD Titan IV launches far exceeds the NDT/x-ray capacities. Either requirements must be reduced, NDT and x-ray capability added, or the commercial Titans will not be able to x-ray and NDT their SRMs.

## CHAPTER IV

### CONCLUSIONS AND RECOMMENDATIONS

#### CONCLUSIONS

Cape Canaveral can not meet the Titan IV Mission Model "doing business as usual." The launch team may be able to meet the mission model by working double shifts, 6 days per week. However, this aggressive schedule is based on no major anomalies impacting the schedule and limited time to perform periodic maintenance and modifications on the facilities. Furthermore, the ability to make up schedule by working during off-shift periods is greatly decreased for there is little time that is not worked. Additionally, there is very little surge capability available in such a schedule.

The aggressive schedule also requires a large increase in the work force of both the contractors and the Air Force personnel who oversee their work. As stated before, the contractors and Air Force agencies are only manned for an 8-hour, five days a week schedule.

Furthermore, for the facility that is capable of processing only one component or set of components at a time, such as the SMAB SRM stacking cells, a problem with the facility or a component in the facility will impact the scheduled launch of all the vehicles which follow it. Redundancy built into the processing facilities can eliminate the problem by providing scheduling flexibility. Moreover, a major anomaly will not tie up the processing facility, and periodic maintenance and modification efforts can be easily worked into the schedule.

With the reductions in facility capacity (and thus, schedule flexibility) listed in Chapter I, the Titan program entered an age of single component processing flows.

a. Instead of being able to check out core vehicles in two vertical cells of the VIB, only one can be used for Titan IVs. Cell 1 is currently used for electrical check out of Titan 34D vehicles and will eventually be used for the Martin Marietta commercial launch vehicle. Cell 2 is used for Titan IV electrical checkout. Cell 3 is being converted to the Centaur Processing Facility. Cell 4 is needed for mechanical processing and storage in order to achieve the 4-per-year launch rate (13:--).

b. Instead of being able to store a set of stacked SRMs in 2 of the SMAB cells while another set is being stacked in the other 2, only one set can be stacked or stored.

c. Instead of being able to use VIB Cell 3 for vertical storage of a fully checked out core vehicle, a Centaur upper stage will be processed in the upper levels while the floor is used to store another Centaur. When the launch rate progresses to 5 per year and more, that storage space will become a highly desired commodity. It would also be valuable to store a core vehicle dedicated to a launch-on-demand requirement.

d. Instead of working on two PLFs concurrently, the technicians are limited to processing only one. Not only is this a choke point to meet the launch rate, but it will be a sore point when one payload out-prioritizes another and moves ahead in the schedule. Its payload fairing may not be able to be processed quickly enough due to PLF Annex physical limitations.

e. Instead of being able to use three transporters to handle Titan IVs, only two are available. Again a great dilemma will occur if a program must launch ahead of others and take a transporter from them. Much of the electrical checkout of the displaced core vehicle will have to be repeated. This may well take up to 40 shifts of rework, impacting that program even more.

The future US space program can not afford the impacts of single vehicle processing flows.

#### RECOMMENDATIONS

Secretary Aldridge asserts, "We must build a space-launch posture that is stronger and more robust than that which existed before. Restoring the status quo should not be our goal. The status quo was too thin" (2:52). After the recent

travesty of space launch mishaps, starting with the shuttle accident, the need for that robustness is now! Putting the flexibility back into Titan launch processing will provide DOD the capability it needs to launch the payloads necessary to maintain the United States' security.

DOD needs to put the flexibility back into the processing of Titan IV vehicles at Cape Canaveral. Reestablishing redundancy into the processing of Titan IV vehicles allows multiple vehicle processing. This can be done as follows:

- a. Create additional PLF processing capabilities. The payload fairing facilities are the physical choke point when processing Titan IV vehicles. The maximum PLFs that can be processed through the PLF Annex working triple shifts, 6 days a week is 5.4 fairings per year. More capacity must be developed if there is ever to be more than 5.4 Titan IV launches per year from Cape Canaveral AFS. Being able to process 2 PLFs concurrently will enable technicians working two 10-hour shifts, 5 days a week to process 8.4 PLFs.
- b. Build a new Solid Motor Assembly Building with at least four cells for stacking. Construct it large enough to stack the entire Titan IV SRM. This will increase the launch complex throughput capacity by eliminating completion of stacking and testing of the SRMs on complex. Furthermore, it should be made capable of processing the Solid Rocket Motor Upgrade (SRMU). If it is built with four stacking cells and two storage cells there would be no problem with SRMs returning from the complex and it would enable storing SRMs for a launch-on-demand capability. Such a facility would enhance Martin Marietta's commercial efforts by allowing them to use the present SMAB for their SRM stacking and checkout.
- c. Construct the Centaur Processing Facility someplace other than in the VIB. This will allow storage of core vehicles in the vertical position, freeing up Cell 2 for processing vehicles. The additional storage would support a launch-on-demand requirement. Additionally, construct the CPF large enough to handle two Centaurs to provide flexibility in processing that upper stage. This also can enhance General Dynamics' commercial efforts.
- d. Configure either VIB Cell 3 or Cell 4 for electrical checkout of Titan IV vehicles. This allows simultaneous work on 2 core vehicles which provides flexibility in scheduling, reduces serial impacts to following vehicles, and enables processing 7.2 core vehicles per year (using 2 crews working 8-hour shifts, 5 days a week). Furthermore, an anomaly on one vehicle will not serially impact others.

e. Configure a third Transporter for Titan IV processing. This provides flexibility in processing, transporting, storing, and troubleshooting core vehicles in the vertical position. It enables 5.4 launches per year (working 8-hour shifts, 5 days a week) and also enhances the Titan IV surge capability.

f. Continue with plans to configure the Titan 34D launch complex for Titan IV vehicles. This allows for simultaneous processing of Titan vehicles and increases additional opportunities for performing periodic maintenance. It also provides a capability to launch Titan IV vehicles if something happens to the dedicated launch complex. Furthermore, it greatly enhances the Titan IV surge capability.

These steps will not only increase Cape Canaveral launch team ability to meet DOD's Titan IV Mission Model, but they will also enhance and, hence, encourage space commercialization efforts. These improvements will, when not in use for DOD missions, provide contractors with greater opportunities to conduct commercial launches.

Not all of these recommendations will provide results quickly. Construction of a second SMAB may take 5 years. Building a new Centaur Processing Facility could take from 2 to 4 years. However, adding PLF processing capability and configuring an additional transporter should only take 2 years and modifying Cell 3 or 4 for Titan IV electrical checkout could be accomplished by 1990.

The author recommends further study of this problem. The majority of the data used to compute throughput capacities was from 8 June 87 data (15:--). With the fruition of the Titan IV activation, more refined data should be available.

Cost trade-off studies in the past have only considered capacity not flexibility. There should be a study initiated to assess the serial delay of launching assets not only in dollars but in terms of security. If a constellation critical to national security must be launched immediately to preserve security and its launch is delayed by 70 days because a set of SRMs are being destacked in the SMAB, what is the price?

Furthermore, the SRM NDT requirements must also be addressed. If requirements remain as they are, more facilities should be constructed. If requirements are reduced, a study should be initiated to determine if there is enough capacity and flexibility to meet the mission models. Additionally, the commercialization requirements must be determined and factored into such a study.

DOD is already making decisions which are putting flexibility back into the Titan IV program. Configuring the Titan 34D launch complex to be compatible with Titan IVs is an excellent example. Using the facility originally built to be NASA's control center for Centaur operations as a Titan IV launch control center while maintaining the VIB Titan launch control centers is another example. DOD must continue in this direction. If the Titan is going to again be the workhorse of the DOD space launch effort, then the facilities must have the flexibility to meet the challenge!



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# GLOSSARY

CELV - Complementary Expendable Launch Vehicle  
CPF - Centaur Processing Facility  
ES - Environmental Shelter  
GPS - Global Positioning System  
IUS - Inertial Upper Stage  
LRE - Liquid Rocket Engine  
MST - Mobile Service Tower  
NDT - Non-Destructive Test(s)  
NSDD - National Security Decision Directive  
NUS - No Upper Stage  
PLF - Payload Fairing  
RIS - Receipt-Inspection-Storage Building  
SPIF - Shuttle Payload Integration Facility  
SRM - Solid Rocket Motor  
SRS - Segment Ready Storage Building  
VIB - Vertical Integration Building

## APPENDICES

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# APPENDIX

## APPENDIX A

TITAN IV PROCESSING  
DOUBLE SHIFTS 6 DAYS A WEEK

CORE VEHICLE - VIB PROCESSING

$$\frac{353 \text{ DAYS}}{\frac{70 \text{ SHIFTS/CORE VEHICLE} + 6 \text{ WEEKEND DAYS}}{2 \text{ SHIFTS/DAY}}} = 8.6 \text{ CORE VEHICLES/YR}$$

EQUATION A.1  
CORE VEHICLES/YEAR - DOUBLE SHIFTS, 6 DAYS/WEEK

SOLID ROCKET MOTORS - SMAB HIGH BAY

$$\frac{353}{\frac{29 \text{ DAYS/SRM SET} + 3 \text{ WEEKEND DAYS} + 5 \text{ IMPACT DAYS}}{2 \text{ SHIFTS/DAY}}} = 15.3 \text{ SETS/YEAR}$$

EQUATION A.2  
SRM SETS/YEAR - DOUBLE SHIFTS, 6 DAYS/WEEK

INERTIAL UPPER STAGE - SMAB EAST BAY

$$\frac{353 \text{ DAYS/YR}}{\frac{103 \text{ SHIFTS/IUS} + 9 \text{ WEEKEND DAYS}}{2 \text{ SHIFTS/DAY}}} = 5.8 \text{ IUSs/yr}$$

EQUATION A.3  
IUSs/YEAR THROUGH A WORK AREA - DOUBLE SHIFTS, 6 DAYS/WEEK

## CONTINUED

$$5.8 \text{ IUSs/YR PER WORK AREA} \times 2 \text{ WORK AREAS} = 11.6 \text{ IUSs/YR}$$

EQUATION A.4  
IUSs/YEAR THROUGH SMAB - DOUBLE SHIFTS, 6 DAYS/WEEK

CENTAUR - VIB CELL 3

$$\frac{353 \text{ DAYS/YR}}{\frac{43 \text{ SHIFTS/CENTAUR} + 4 \text{ WEEKEND DAYS}}{2 \text{ SHIFTS/DAY}}} = 13.6 \text{ CENTAURS/YR}$$

EQUATION A.5  
CENTAURS/YEAR THROUGH VIB CELL 3 - DOUBLE SHIFTS, 6 DAYS/WEEK

PAYLOAD FAIRINGS - VIB PAYLOAD FAIRING ANNEX  
(TRIPLE SHIFTS, 6 DAYS/WEEK)

As explained in Chapter III, PLF work days are affected by curing time. Therefore, when working triple shifts, dividing the total shifts to process a PLF when working a single shift operation by 3 will not result in the correct number. When the cure time is factored in the number of triple shift workdays becomes 55 (13:--).

$$\frac{353 \text{ DAYS/YR}}{55 \text{ WORK DAYS} + 10 \text{ WEEKEND DAYS}} = 5.4 \text{ PLFs/YR}$$

EQUATION A.6  
PLFs/YEAR - TRIPLE SHIFTS, 6 DAYS A WEEK

## CONTINUED

### LAUNCH COMPLEX

CORE ARRIVAL TO MATE  $\frac{38 \text{ SHIFTS}}{2 \text{ SHIFTS/DAY}} + 4 \text{ WEEKEND DAYS} = 23 \text{ DAYS}$

MATE TO LAUNCH            28 DAYS                            28 DAYS

REFURB TO LAUNCH     $\frac{13 \text{ SHIFTS}}{2 \text{ SHIFTS/DAYS}} + 1 \text{ WEEKEND DAY} = 8 \text{ DAYS}$

LAUNCH TO LAUNCH CAPABILITY                            59 DAYS

#### EQUATION A.7

LAUNCH TO LAUNCH CAPABILITY - DOUBLE SHIFTS, 6 DAYS/WEEK

$$\frac{353 \text{ DAYS/YR}}{59 \text{ DAYS/LAUNCH}} = 6.0 \text{ LAUNCHES/YR}$$

#### EQUATION A.8

LAUNCHES FROM A COMPLEX/YEAR - DOUBLE SHIFTS, 6 DAYS/WEEK

### TRANSPORTERS

The 28 days from satellite mate to launch are scheduled for work 24 hours per day seven days a week. Therefore, double shifting will not reduce them. There are 120 other shifts the transporter encounters which may be double shifted. So the 28 days must be added in after factoring the double shifting.

$$\frac{353 \text{ DAYS/YR}}{\frac{120 \text{ SHIFTS/TRANSPORTER} + 28 \text{ DAYS} + 10 \text{ WEEKEND DAYS}}{2 \text{ SHIFTS/DAY}}} = 3.6 \text{ LAUNCHES/YR}$$

#### EQUATION A.9

LAUNCHES PER TRANSPORTER - DOUBLE SHIFTS, 6 DAYS/WEEK



## CONTINUED

3.6 LAUNCHES/YR PER TRANSPORTER X 2 TRANSPORTERS = 7.2 LAUNCHES/YR

EQUATION A.10  
LAUNCHES/YEAR FROM TRANSPORTERS - DOUBLE SHIFTS, 6 DAYS/WEEK

## APPENDIX

### APPENDIX B

#### SOLID MOTOR ASSEMBLY THROUGHPUT SRM FLIGHT SETS PER YEAR

It takes 25 shifts to stack a set of Titan IV SRMs in the SMAB and 4 shifts to mate the SRMs to the core vehicle. Five days of impact should also be added to the computation. Factoring in the weekend days encountered yields 46 days (Equation B.1) for processing one set of Titan IV SRMs through the SMAB.

$$\frac{29 \text{ SHIFTS/SET} + 12 \text{ WEEKEND DAYS} + 5 \text{ IMPACT DAYS}}{1 \text{ SHIFT/DAY}} = 46 \text{ DAYS/SET}$$

#### EQUATION B.1 DAYS/TITAN IV SRM SET

There are 38 shifts required to stack a Titan 34D or Titan III SRM set. Five more shifts are required to mate the SRMs to the core vehicle. Five impact days are factored into the equation. Additionally, five shifts are required to reconfigure the cells from Titan IV SRM stacking to Titan 34D/III stacking, and then five more are required to return the cells back to Titan IV configuration. Adding the weekend days encountered yields 80 days (Equation B.2) to process a Titan 34D or Titan III SRM set through the SMAB.

$$\frac{43 \text{ SHIFTS/SRM} + 10 \text{ RECONFIGURATION SHIFTS/SET} + 22 \text{ WEEKEND DAYS} + 5 \text{ IMPACT DAYS}}{1 \text{ shift/day}} = 80 \text{ DAYS/SET}$$

#### EQUATION B.2 DAYS/TITAN 34D/III SRM SET

## CONTINUED

To determine how many SRM sets can be processed through the SMAB the days/Titan IV is multiplied by the number of desired sets. The quotient is subtracted from the number of days available in the year. The result is the number of days available to process Titan 34D/III SRM sets. Thus, the number of Titan 34D/III sets possible is derived by dividing the remaining days by the time it takes to process a set.

$$4 \text{ TITAN IV SETS} \times 46 \text{ DAYS/SET} = 184 \text{ DAYS TO PROCESS 4 SETS}$$

$$353 \text{ DAYS} - 184 \text{ DAYS} = 169 \text{ DAYS}$$

$$\frac{169 \text{ DAYS/YR}}{80 \text{ DAYS/SET}} = 2.1 \text{ TITAN 34D/III SETS/YEAR}$$

$$\text{EQUATION B.3} \\ \text{TITAN 34D/TITAN III SRM SETS/YEAR}$$

$$\frac{29 \text{ SHIFTS/SET} + 3 \text{ WEEKEND DAYS} + 5 \text{ IMPACT DAYS}}{2 \text{ SHIFTS/DAY}} = 23 \text{ DAYS/SET}$$

$$\text{EQUATION B.4} \\ \text{DAYS/TITAN IV SRM SET - DOUBLE SHIFTS, 6 DAYS/WEEK}$$

$$\frac{43 \text{ SHIFTS} + 10 \text{ RECONFIGURATION SHIFTS} + 5 \text{ WEEKEND DAYS} + 5 \text{ IMPACTS DAYS}}{2 \text{ SHIFTS/DAY}} = 37 \text{ DAYS/SET}$$

$$\text{EQUATION B.5} \\ \text{DAYS/TITAN 34D/TITAN III SRM SET - DOUBLE SHIFTS, 6 DAYS/WEEK}$$

## CONTINUED

4 TITAN IV SETS X 23 DAYS/SET = 92 DAYS

353 DAYS - 92 DAYS = 261 DAYS

261 DAYS/YR = 7.1 TITAN 34D/TITAN III SETS/YEAR  
37 DAYS/SET

### EQUATION B.6

TITAN 34D/TITAN III SRM SETS/YEAR - DOUBLE SHIFTS, 6 DAYS/WEEK

END

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